eRHIC Luminosity and IR Issues

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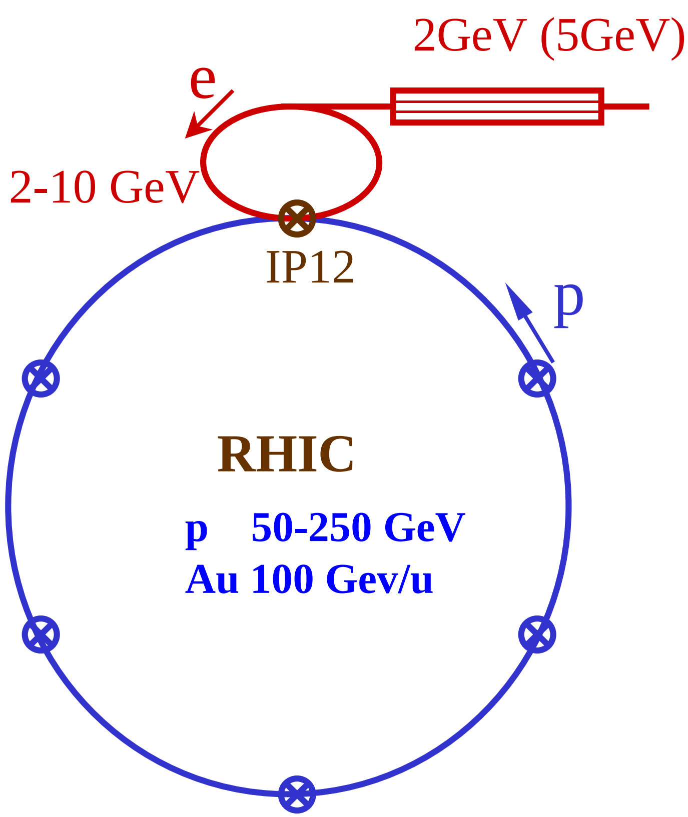
EIC Objectives

- e-p and e-ions collisions
- 5-10 GeV electrons; 25-250 Gev protons; 100 Gev/u Au
- Luminosity:
  - ***L = (0.3-1)x10^{33}*** for e-p collisions
  - ***L = (0.3-1)x10^{31}*** for e-Au collisions
- Polarized electron and proton beams
- Longitudinal polarization at collision point; 70%
- 35 nsec minimum separation between bunches

eRHIC collider layout



- e-ring is 5/16 of RHIC ring
- Collisions at one IP
- 28 MHz collision rate
- Unpolarized electron source
- Electron beam polarization by the synchrotron radiation
- e-ring lattice based on ”superbend” magnets

Luminosity and beam-beam limits

Beam-beam parameters (round beams):

$$\xi_e = \frac{N_i}{\epsilon_e}\left(\frac{r_e Z}{4\pi\gamma_e}\right) \quad (1) \longrightarrow 0.05$$

$$\xi_i = \frac{N_e}{\epsilon_i}\left(\frac{r_i (v/c)_i}{4\pi Z}\right) \quad (2) \longrightarrow 0.005$$

Reasonably achievable values:

Emittance subscripts are correct! For example, e-cooling reduces ϵ_i and allows N_e to be reduced.

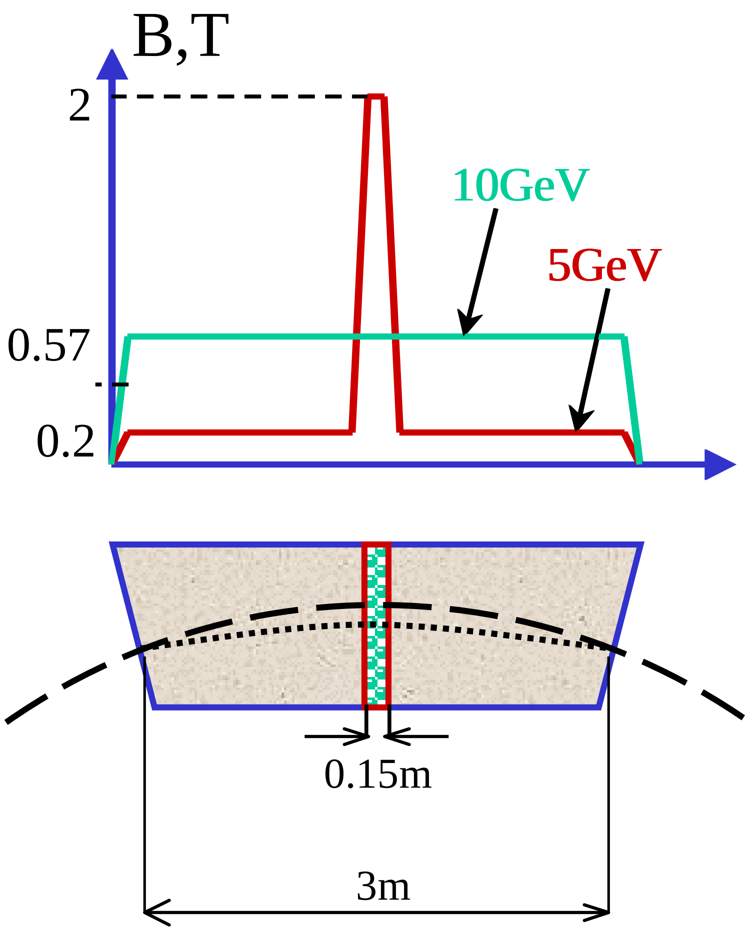
Electron-ion luminosity can be written

$$L = F_c\, \xi_e \xi_i\, \sigma_e'^* \sigma_i'^* \left(\frac{4\pi\gamma_e\gamma_i}{r_e r_i}\right) \quad (3)$$

- When beam-beam limits and angular apertures have been met, $\xi_e\xi_i\sigma_e'^*\sigma_i'^*$ is fixed.

- Round beams:
  $\nu_x=\nu_y$, $\beta_x=\beta_y$ for electrons
- Matching of the e and p beam sizes is crucial.

Superbend magnet



$$\tau_{pol}^{-1} \propto \gamma^2 B^3$$

$$\Delta E_{SRL} \propto \gamma^2 B^2$$

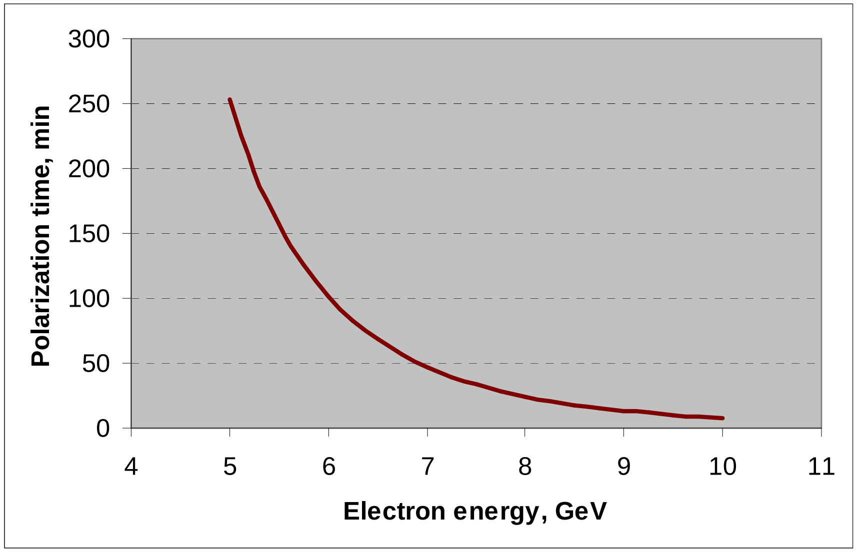
The desired balance:
short polarization time at the acceptable level of synchrotron radiation losses

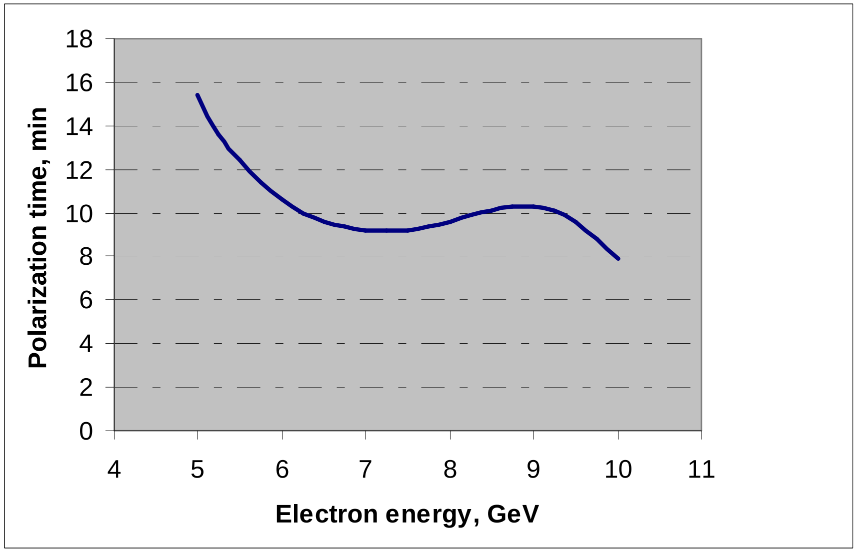
Flexible control of the beam emittance

Issues:

- Accomodation of radiated power (7MW radiated at 10 GeV)
- Orbit lengthening versus beam energy

Polarization time with superbend





- Magnet bending field scaled proportionally with energy

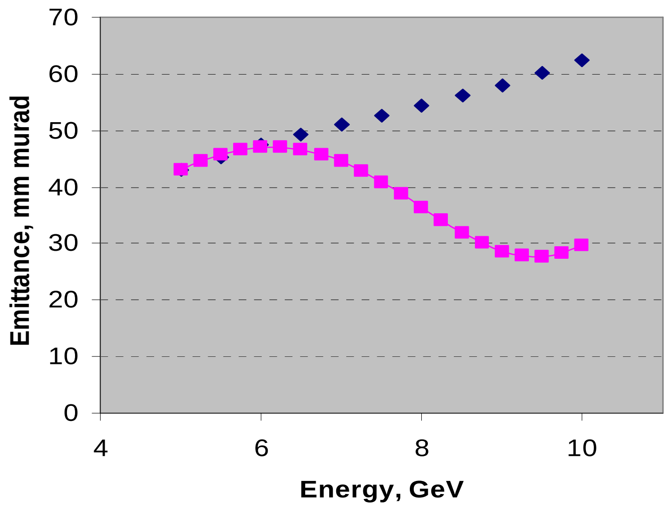
$$\boxed{\tau_{pol}^{-1} \propto \frac{\gamma^5}{\rho^3}}$$

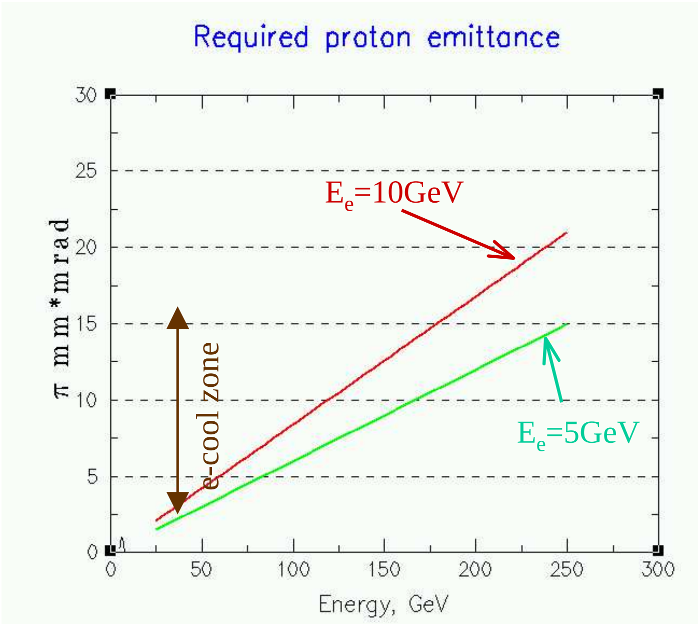
- The superbend control of polarization time.

8-15min polarization time is achievable.

Beam emittance control

Electron emittance versus electron energy
for different superbend settings





- Required normalized emittances for Au: 5-8 Pi mm*mrad at 5-10 GeV electron energies;

  The cooling is required.
- Cooling of the proton beam is required for proton energies below 200 GeV

Main parameters for e-ring with superbends

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Parameters	e-ring	ion ring	
		p	Au
C, m	1022	3833	
E, GeV	5–10	250	100/u
n_b	96	360	
N_b	$1 \cdot 10^{11}$	$1 \cdot 10^{11}$	$1 \cdot 10^{9}$
I, A ε_{rms},mm rad β^*, cm σ^*, mm ξ	0.45 45–25 10 0.07–0.05 0.05	0.45 17–9 27 0.07–0.05 0.005	
L, cm^{-2} s^{-1}		$(0.5\text{-}0.9) \cdot 10^{33}$	$(0.5\text{-}0.9) \cdot 10^{31}$

Required ion ring improvements

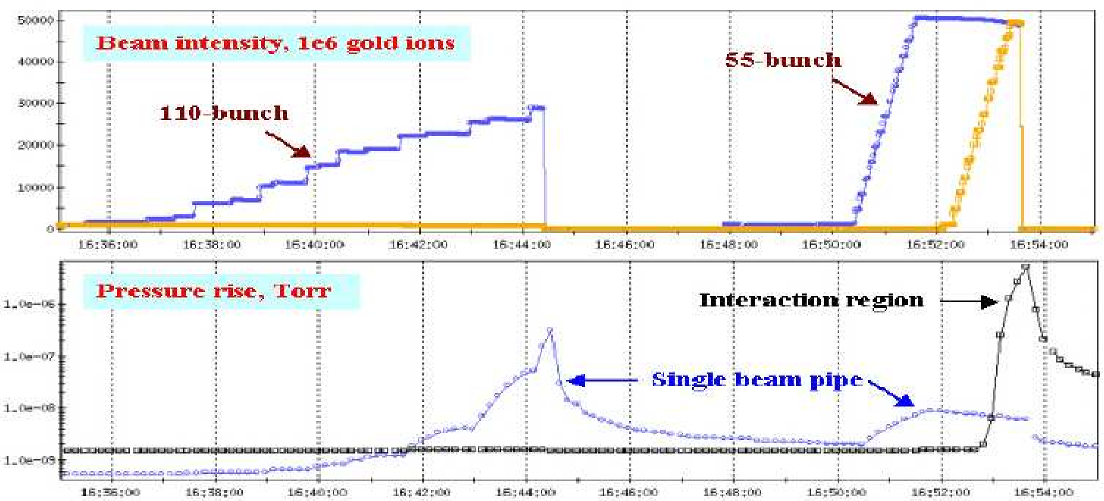
- Transverse cooling for ions and lower energy protons
  - Electron cooling ptoject in the RHIC is underway
- n_b from 60-120 to 360 bunches
  - Injection system development needed (from discussions with W.Fischer):
    - Faster injection kicker (~20 ns risetime) OR
    - RF Manipulation (barrier bucket cavity and bunch merging) in RHIC
  - Physical limitations to be studied and overcomed:
    - Vacuum pressure rise, electron cloud. Remedies:
      - Vacuum chamber baking; using solenoids; beam scrubbing; special coating
    - Long range beam-beam effects (issue for beam separation scheme).

- Reducing β^* from 1m to $\beta^* < 0.5$m
  - Interaction region re-design
  - Proton (ion) bunch length reduction issue

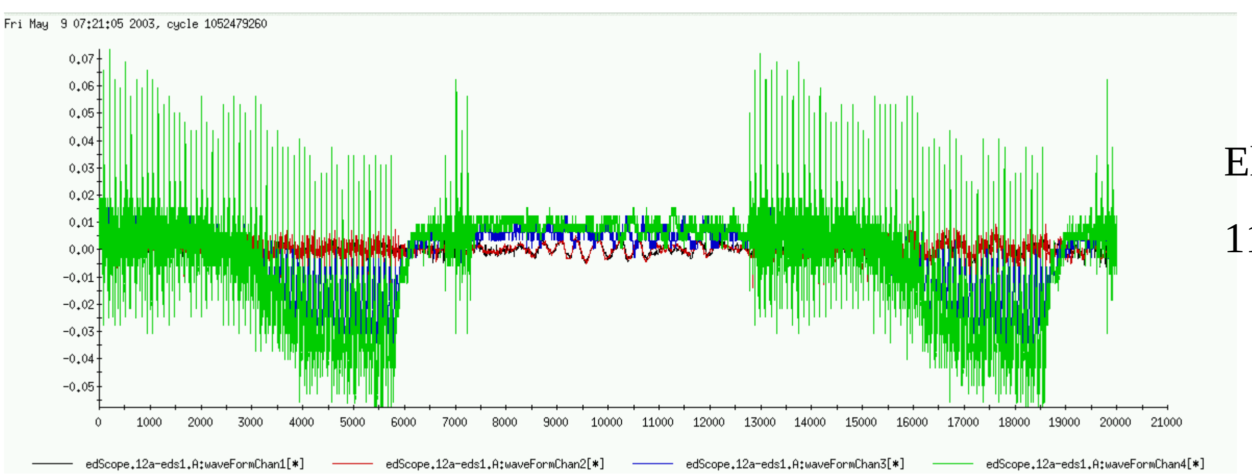
    Longitudinal cooling (electron, stochastic) is required

Pressure rise, electron cloud examples (S.Y.Zhang + pr/ec team)

Pressure Rise at Injection, I



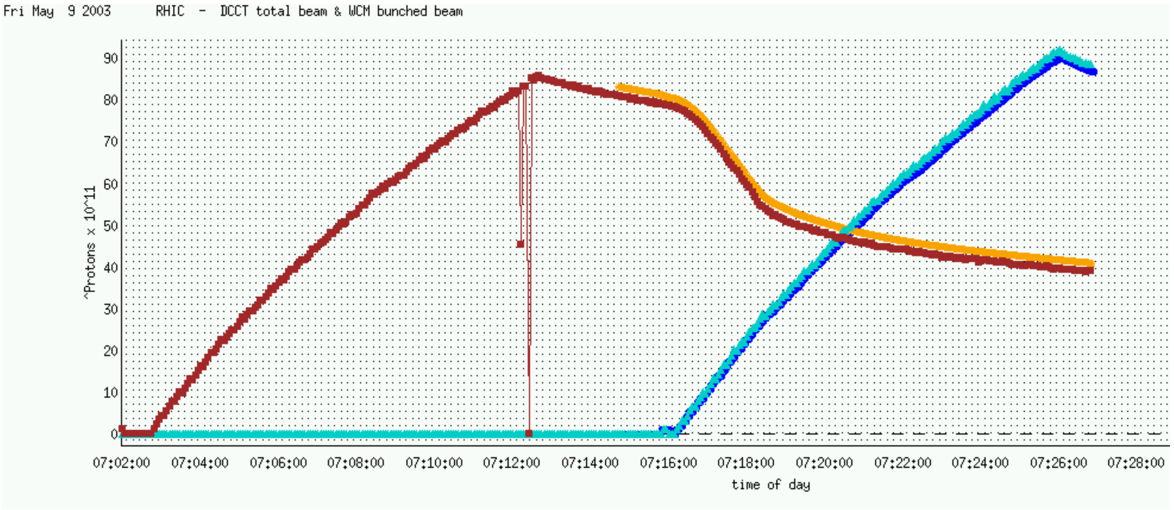
Pressure rise with 110 bunches of Au ions



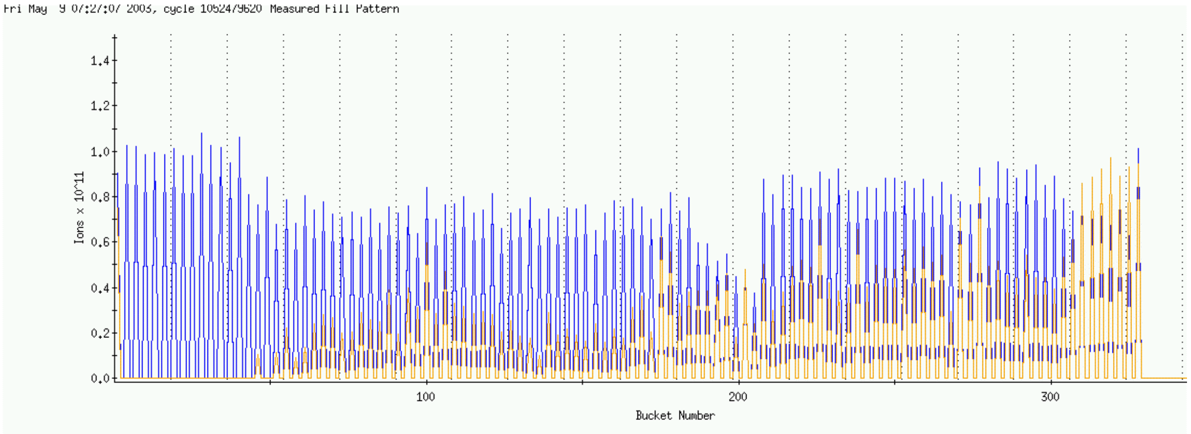
Electron detector signal at IR12 at

112 bunches proton beam studies

Parasitic beam-beam with 110 proton bunches



Lifetime deterioration while filling another ring



Resulting bunch pattern

IR Design Criteria

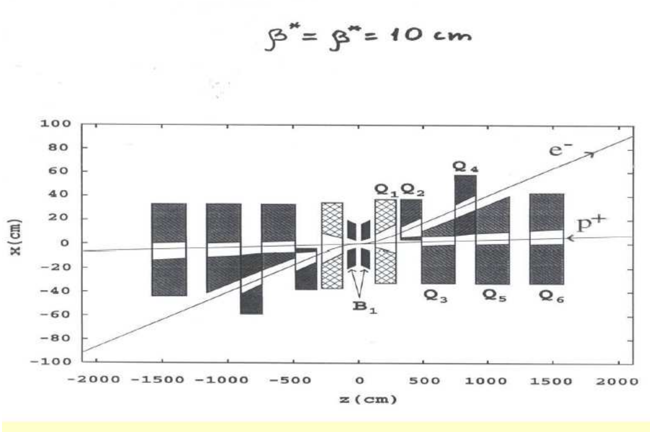
- Separation scheme to avoid parasitic beam-beam collisions (35nsec distance between bunches).

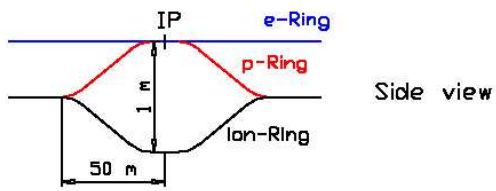
  The separation should work well in all energy range: 5-10 GeV electrons, 25-250 GeV protons.

- Focusing to low β^* in both rings. What is lowest β^* achievable?
- Longitudinal polarization in interaction point.
- Minimal depolarization from separation and spin rotation schemes. Spin transparency conditions
- Detector background, protection from synchrotron radiation issues

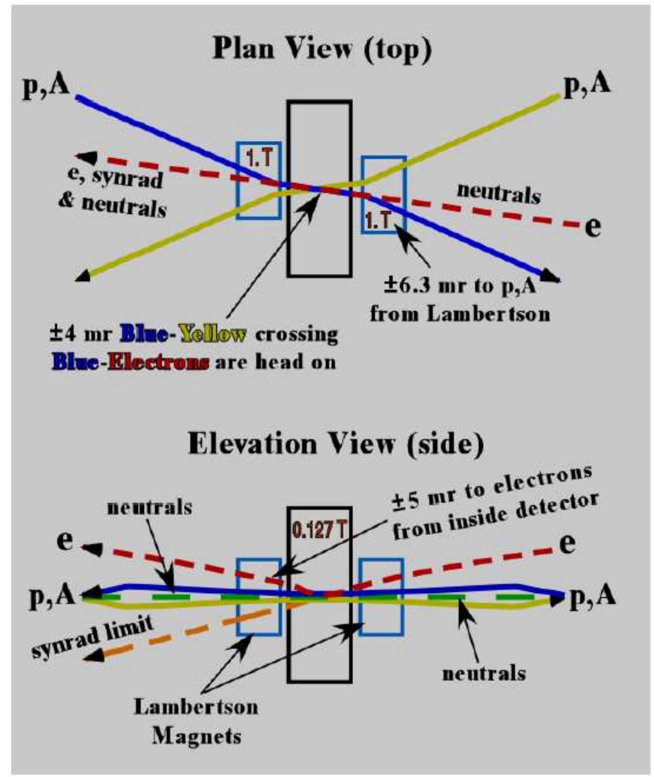
IR Design

Horizontal separation scheme



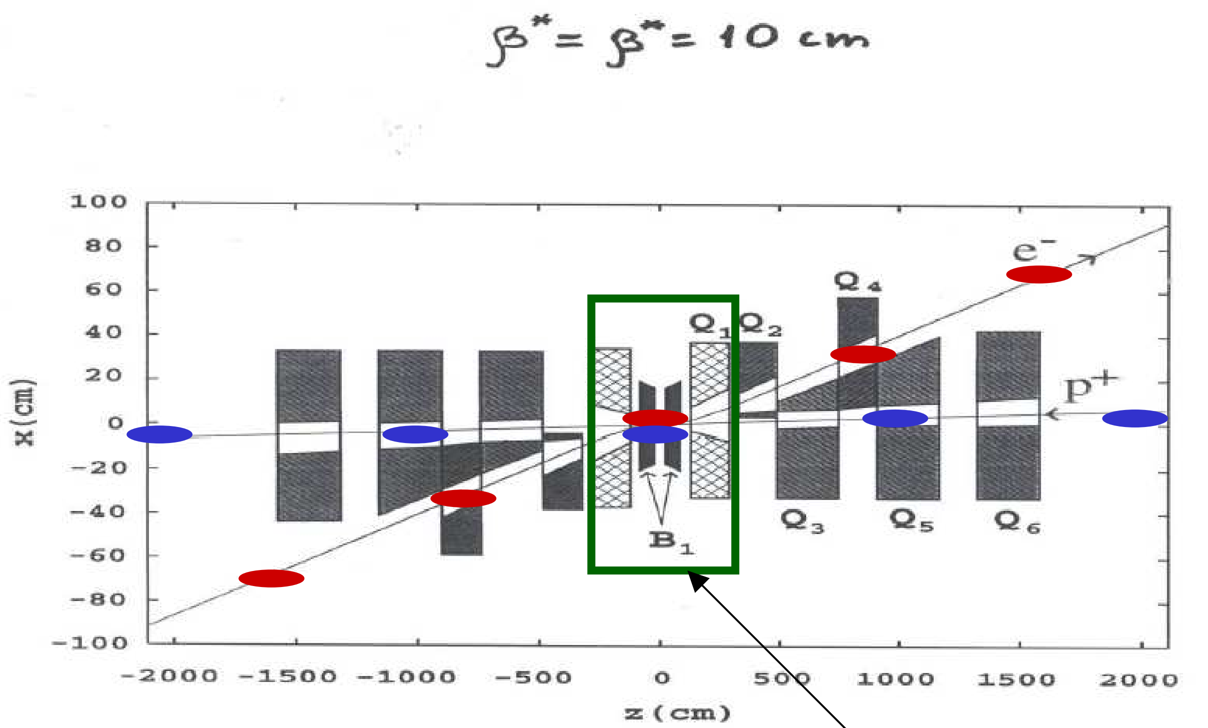


Vertical separation scheme



- IR development proceeds in close link with the detector design
- Detector background and protection from synchrotron radiation issues

Beam separation



Detector area

Summary:

- Presently we have polarized e-p and unpolarized e-ion beam collisions in the center of mass energy range of 30-100 Gev and at luminosities up to 0.9×10^{33} $cm^{-2}s^{-1}$ for e-p and 0.9×10^{31} $cm^{-2}s^{-1}$ for e-Au collisions.

- Should we aim to higher luminosity number? Which number?

- Some quite urgent interaction region design work is neccesary to get a clear solution for it in coming monthes.